Technical Report
CMU/SEI-87-TR-12
ESD-TR-87-113

Carnegie-Mellon University
Software Engineering Institute

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This technical report was prepared for the

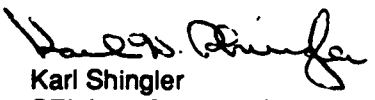
SEI Joint Program Office
ESD/XRS
Hanscom AFB, MA 01731

The ideas and findings in this report should not be construed as an official DoD position. It is published in the interest of scientific and technical information exchange.

Review and Approval

This report has been reviewed and is approved for publication.

FOR THE COMMANDER



Karl Shingler
SEI Joint Program Office

This work is sponsored by the U.S. Department of Defense.

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The Analysis of the Technical Order Production Process at Ogden Air Logistics Center and Recommendations for the Improvement of the Process

Abstract. This report details the process used by Ogden Air Logistics Center to maintain Operational Flight Program Technical Orders for the F-16 airplane. It is of particular interest to Ogden because it makes recommendations for the improvement of the process and also recommendations for technology insertion. Since the technical order modification process is not entirely different from documentation maintenance activities in industry, this report is of general interest and widely applicable to documentation processes in the software community at large.

1. Introduction

As the need for mission-critical software systems increases, Post Deployment Software Support (PDSS) activities will require increased priority in planning. The increasing complexity of systems exacerbates the problem. PDSS is "the sum of all activities required to ensure that, during the production/deployment phase of a mission-critical computer system's life, the implemented and fielded software/system continues to support its original missions, and subsequent mission modifications and product improvements."[1] PDSS, therefore, includes not only software "maintenance" but also the activities required for overall system support.

The Software Engineering Institute (SEI) recognizes the importance of PDSS activities in the life cycle of mission-critical systems. In March 1986, SEI personnel met with representatives of the Air Force Logistics Command (AFLC) at Ogden Air Logistics Center (OO-ALC), Hill Air Force Base, Utah, to determine if there were areas in PDSS that the SEI could address. The AFLC representatives described the activities performed at air logistics centers and problems encountered in those activities. As a result of this meeting, the SEI authorized a feasibility study to determine how it might best interact with the PDSS community.

Between April 1986 and July 1986, SEI staff members investigated PDSS activities through documentation reviews and interviews with key Department of Defense (DoD) personnel. The following documents are representative of those reviewed:

- DoD Directive 5000.29, Management of Computer Resources in Major Defense Systems
- SECNAVINST 5000.32, Management of Embedded Computer Resources in Department of Navy Systems
- CODSIA Report 13-82, DoD Management of Mission-Critical Computer Resources

[1] Final Report of the Joint Logistics Commanders Workshop on PDSS for Mission-Critical Computer Software, June 1984.

- National Bureau of Standards Special Publication 500-106, Guidance on Software Maintenance.

Ogden ALC participated in the SEI project and suggested that the F-16 program be used as a case study. Thus, initial investigations by the SEI focused on Air Force PDSS activities. In addition, interviews were conducted with key personnel from:

- Materiel Management Engineering (OO-ALC/MME)
- Engineering Reliability Branch (OO-ALC/MMAR)
- General Dynamics, Ft. Worth, Texas
- AFLC Headquarters (HQ AFLC/MME) and the Air Force Human Resources Labs (AFHRL).

The SEI also established a dialogue with the Joint Logistics Commanders Computer Resources Management (JLC/CRM) PDSS subgroup and began to participate in the subgroup's meetings.

To understand PDSS in a broader context and to learn how other branches of service view and execute PDSS activities, the SEI also held interviews with personnel from:

- Marine Corps Tactical System Support Agency (MCTSSA)
- Fleet Combat Decision System Support Agency (FCDSSA)
- Pacific Missile Test Center (PMTC)
- Army Materiel Command (AMC).

One common theme that emerged from all the interviews is that PDSS facilities are experiencing difficulties developing and delivering technical orders (TOs), which are documents that accompany software releases. Some of the reasons offered were inadequate staff, insufficient support equipment, government regulations, and reliance upon contractors. Since the management of the TO modification process presents a significant challenge, and directly relates to the availability of mission-critical systems, the SEI initiated the PDSS Information Management Project. This project has two major tasks: 1) analyze and model the TO process and 2) determine problem areas related to the production of TOs. Project reports will propose solutions to the problems identified.

The following section provides more detail on Ogden's activities and the SEI project plan developed to investigate them.

2. Project Overview

2.1. Ogden Air Logistics Center Activity

Ogden Air Logistics Center, located at Hill AFB, Utah, is the management ALC for the F-16 and F-4 airplanes. Software changes authorized and performed at Hill (or contracted to General Dynamics) require the modification of two categories of documents: 1) engineering documentation and 2) TOs (pilot and technician user guides). The TOs must accompany the release of the software to the field. However, TO production, which takes six to nine months to complete, often does not begin until the software changes are completed. Therefore, release of the software is delayed by that length of time.

In an attempt to solve this problem, the Air Force initiated the Automated Technical Order System (ATOS) program. ATOS is a collection of off-the-shelf hardware and software that provides a means for combining text and graphics and producing photo-ready pages. Hill was the first to receive a release of the Phase 1 system. However, given the rapid evolution of electronic publishing technology and the length of the procurement cycle, this system falls short of solving the problem.

Ogden ALC management recognizes that if the entire process—from editing to producing TOs—were handled electronically, the revision time could be greatly reduced. OO-ALC requested the assistance of the SEI to explore the use of electronic documentation automation workstations in the TO modification process.

2.2. Task Overview

The purpose of the PDSS project is to identify, recommend, and install technologies that improve the documentation production process specific to TOs. PDSS project members will investigate this process across several DoD programs and review current DoD initiatives in the area of documentation production. Based upon the results of this investigation, project members will make recommendations for the following:

- Changes to the process used by OO-ALC to produce TOs. These recommended changes will eliminate delays, introduce parallelism, and enhance coordination and communication between participants in the process.
- Introduction of technology to automate certain functions.

The remainder of this report contains an analysis of the documentation production process and recommendations concerning that process.

3. Description of TO Modification Process

3.1. Background

One important dimension of the project's activities entails understanding, documenting, and describing the process currently used at OO-ALC to produce and distribute TO modifications corresponding to the F-16 A/B OFP avionics software block changes. This process description forms a base from which project members formulate recommendations about possible improvements and technological enhancements that will streamline the process. Furthermore, this description is expected to be of value to those involved in any phase of the process or its management, by clarifying the entire process and, thus, enhancing their appreciation for the part their role plays in its successful execution.

It is useful to have a basic perspective of the scope and magnitude of the effort to produce TO modifications. General Dynamics reports that the set of F-16 A/B separate TOs comprise approximately 141,000 pages. In addition, they report that a "typical F-16 A/B Operational Flight Program (OFP) block change" affects:

- 80 aircraft TOs (total of 3,817 pages changed)
- 24 commodity TOs (total of 83 pages changed)
- 24 Time Compliance Technical Order (TCTOs) (total of 51 pages created).

Many of the affected TOs are modified in relatively minor ways. For example, many maintenance and job guide TOs involve changes in part numbers to correspond to the software change; and many maintenance and operational TOs, as well as job guides and checklists, must be modified because the OFP software identification number changes. (This number appears in numerous diagrams depicting the expected display on the "Power-On Panel" when the system is first turned on.) Although these changes are relatively easy to make once identified, their identification from 141,000 pages of manuals can be quite challenging. On the other hand, a relatively small number of TOs undergo more substantial modifications. These include several operational manuals, since many software changes typically have an impact on the "user interface".

3.2. Process Description

The process description presented here applies to the steps that normally occur for TO modifications corresponding to the F-16 A/B OFP avionics software block changes. It does not attempt to describe the situation for safety or other emergency changes or for TO changes of a purely editorial nature (e.g., to correct errors or improve clarity). The changes examined are necessitated by changes to the underlying weapon system, while editorial changes are not. Moreover, this process is not intended to apply to other types of weapon system modifications not involving software. Finally, although project members have attempted to describe the "normal" process, only one software block change has been fielded in which OO-ALC had a major role in TO modifications (15S1). Thus, actual historical experience is limited. Accordingly, project members have focused more on what is expected to occur for the change currently in process (15S2) than on seeming peculiarities of the S1 block. For example, the issuance of interim operational supplements followed by normal operational supplements in the S1 block was judged to be abnormal and, hence, is not depicted in the process description presented.

This description, which is the result of numerous interviews with the principals involved, represents the current best understanding of the normal process by PDSS project members. Nevertheless, project members will develop this process description more fully as work proceeds and as new information becomes available. In addition, project members will develop a similar description for the corresponding process of TCTO generation and distribution. Both the TO and TCTO processes will be synchronized with major events comprising the actual software change process. However, the major focus remains on the TO process.

The TO process with which project members are concerned is depicted in diagrammatic form in Figure 1. The following explains the diagram and walks through the process at a fairly high level. Each activity is described more fully in Appendix C.

The structure of Figure 1 loosely follows that of a data flow diagram, a technique widely used in systems analysis work. The fundamental focus of this approach is to trace the flow of data or information through the system. The lines with arrowheads in the figure represent the data flows between activities and data stores. Data stores are repositories where data are stored for future reference. They are represented in the diagram by short, wide rectangles, open at the right-hand side; there are four stores shown in the figure, numbered S1. S2, S3, and S4. S2 (TO Libraries) is shown twice for the sake of convenience in drawing the data flows. The seven round-cornered rectangles represent the basic activities carried out in the system. In this case, these activities occur in a basically sequential fashion. Finally, squares are used to depict external activities, personnel, etc. and to represent Technical Order Distribution Offices (TODOs), the recipients of the modified TOs.

Before the process of modifying F-16 TOs begins, the nature of the software changes to be made has been identified, analyzed, and presented to the proper authorities for approval. The TO modification process can begin once the software design work is well developed, since the definition of the changes and their basic method of implementation is reasonably stable at that point. While the software design work is progressing, MMAR personnel ensure that a list of the TOs affected by the software changes will be provided to MMEC personnel.

The first major activity in the TO modification process then begins—"1.0 Identify and Draft Modifications to Affected TOs" in Figure 1. The bulk of this work is accomplished by MMEC personnel who have been involved in the software design; however, some TO modifications are also prepared by MMARC personnel. This activity is accomplished in a purely manual fashion and involves thumbing through thousands of pages of TOs to look for text and diagrams that need to be modified. These draft changes are then marked in red pen (red-lined). This activity involves reference to the current version of the affected TOs and sometimes to detailed software descriptions compiled in an avionics manual. Several different individuals accomplish this activity, and there is wide variation in the timing of its completion.

The red-lined TOs are then passed to MMARC for review and ultimate approval — "2.0 Review and Draft Modifications to Affected TOs" in Figure 1. TOs may be passed back to MMEC if they need to be reworked before approval. An AFLC Form 252 is prepared and signed for each affected TO, detailing the changes to be made. These TO changes are held until the software changes have been validated and verified, and then they are forwarded to MMEDT as a single package.

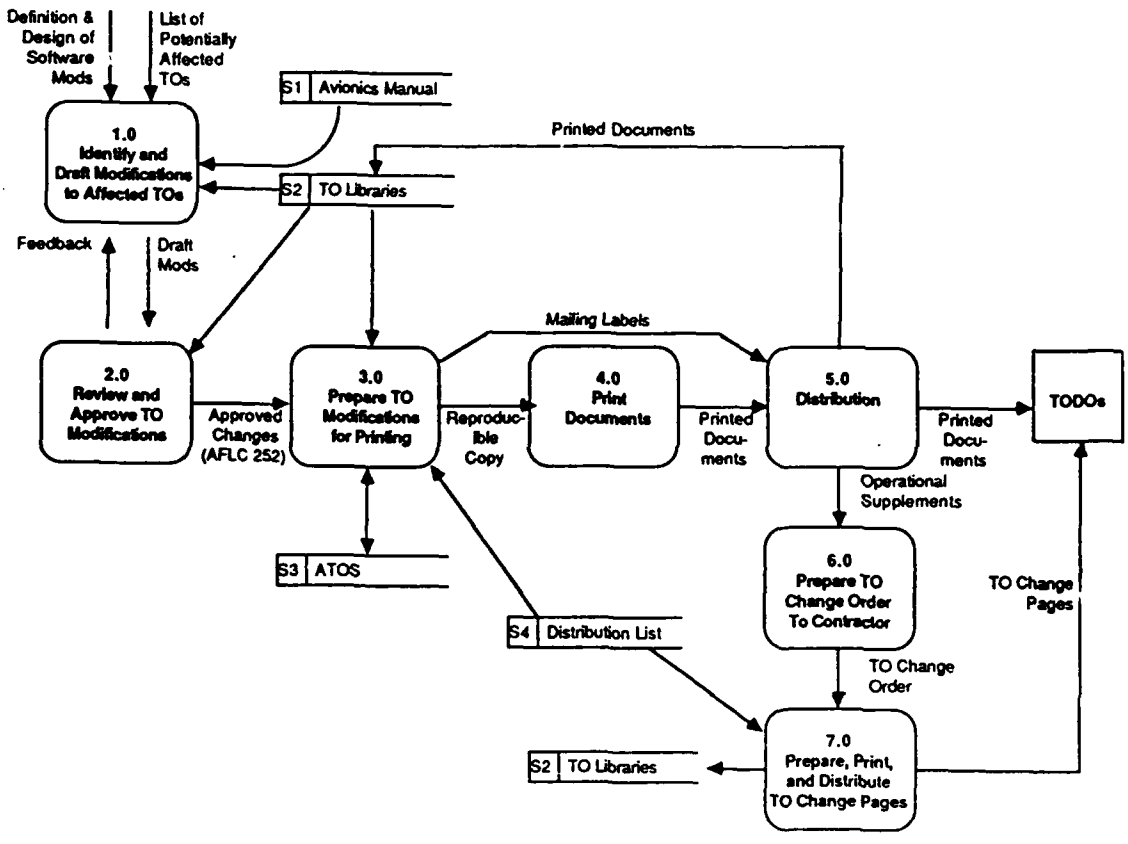

Figure 1: TO Modification Process

This package of approved TO changes authorizes MMEDT to compose and typeset reproducible copy of the formal documents that detail the changes and are issued to the field. This is depicted in Figure 1 as activity "3.0 Prepare TO Modifications for Printing." The actual production work of composing, drafting graphics, typesetting, and merging text and graphics may be performed by OO-ALC personnel or by a local overflow contractor. Normally, one of two types of TO modifications are prepared, depending on whether the affected TO is physically maintained at OO-ALC or by General Dynamics. In the latter case, which applies to most (if not all) affected TOs, an operational supplement (op sup) is normally developed by MMEDT as the document form distributed to the field. For TOs physically maintained by OO-ALC, such as commodity TOs, the ATOS system is normally used to produce change pages for distribution.

One other major function carried out in the third activity is planning for printing and distribution. This entails working with the GO22 system at Oklahoma City Air Logistics Center (OC-ALC) to determine the number of copies of each affected TO document to print, and to acquire mailing labels for all TODOs on the initial distribution list for each TO. These labels are forwarded to the TO warehouse (5.0 Distribution). A reproducible copy of each TO modification document (whether change pages or op sups) is forwarded to the Directorate of Administration, Reprographics Division (DARA) for printing, along with instructions on how many copies to print and an indication of the turnaround time allowed for printing (normally 15 days).

The fourth activity shown in Figure 1 is labeled "4.0 Printing." The purpose of this activity is to print the required number of copies of each op sup or group of TO change pages within the allowed turnaround time. In most cases, the actual printing or reproduction is accomplished either at the print shop on base or by one of several local area printers on direct deal contracts through the Government Printing Office (GPO). Deadlines for printing are usually met. The printed documents are then forwarded to the TO warehouse for distribution.

The distribution activity is depicted in Figure 1 as "5.0 Distribution" and is managed by the TO Distribution Control Office (TODCO), a MMEDT function. The TO documents are packaged and addressed using the mailing labels acquired from the GO22 system at OC-ALC, then they are metered and mailed. However, shipment of these TO modifications must be coordinated with the shipment of the actual computer tapes containing the modified software and the corresponding TCTOs, as this is all concurrent release material. This is the end of the process for those TOs for which change pages were produced.

Additional steps are applied for the majority of the TOs for which op sups were produced. In this circumstance, copies of the op sups are held on file at MMEDT and activity 6.0 in the figure begins — "6.0 Prepare TO Change Order to Contractor." The purpose of this activity is to eventually incorporate TO changes published as op sups into actual TO change pages. Since General Dynamics is contracted to maintain these TOs, they must prepare the change pages. Normally, MMEDT personnel will wait until the next time a change processed through OO-ALC/MMEDT is to occur to one of these TOs. At that point, they will direct General Dynamics to incorporate the new change, as well as those previously issued in the op sup, into formal change pages. In general, this new change is entirely unrelated to the previous software-related changes. It should also be noted that this activity proceeds independently for each affected TO, so some op sups are incorporated into change pages before others are. The directive to General Dynamics is issued as a TO Change Order.

Upon receipt of this order, General Dynamics then performs the final activity shown in Figure 1 — "7.0 Prepare, Print, and Distribute TO Change Pages." General Dynamics is contractually permitted 90 days to prepare a reproducible copy of the change pages. In addition, 45 days are allowed for the actual printing of the documents. Once again, the GO22 system provides information on the number of copies to print and supplies the mailing labels. The print shop usually mails out the documents directly.

The preceding paragraphs describe the PDSS project members' understanding of Ogden's current process. The next section discusses an analysis of this process and identifies a number of issues that appear to be problematic. Subsequent sections include recommendations for streamlining the TO modification process. Recall that the PDSS project's primary goal is to reduce the time delay between when the software changes are ready to be fielded and when the TO modifications are ready to be distributed. Cost avoidance, savings, improved accuracy, and so forth are of secondary importance.

4. Analysis of the Process

4.1. Overview

The problems and corresponding recommended solutions fall into two major categories: those that could be largely alleviated by changes to manual methods and procedures without introducing new technology, and those where introducing additional technology is expected to have a substantial impact. In addition, project members have identified some problematic issues that are deeply rooted in the current F-16 TO modification process and cannot be substantially influenced in the near term. In a later report, project members will identify lessons learned from the analysis of those problems and recommend that they be applied to future acquisition activities. Finally, it must be noted that this analysis is preliminary and subject to future modification and enhancement.

4.2. Broad Issues

4.2.1. Division of Labor Between OO-ALC and General Dynamics

One major issue that has affected the broad structure and circumstances of the present process is that OO-ALC needs to perform some TO modifications in house, while others are contracted out to General Dynamics. One aspect of this issue is that the Program Management Responsibility Transfer (PMRT) for the F-16 A/B separate TOs was not a "clean" transfer. Although PMRT formally occurred in October 1985, several thousand residual tasks remain to be accomplished on these TOs. These tasks are managed and paid for by the F-16 Systems Program Office (SPO) and performed by General Dynamics. Since this activity occurs rather independently of OO-ALC, at least two streams of modifications are occurring: those processed through the Systems Program Manager (SPM) at OO-ALC, and those processed through the SPO and performed by General Dynamics. This is one substantial reason why control of the originals for most F-16 TOs remains at General Dynamics.

Another aspect of this issue is that the time frame allowed for General Dynamics to make TO modifications (90 days) is unacceptably long for effecting modifications corresponding to software changes. Therefore, OO-ALC/MMEDT issues op sups for these changes and expects to be able to prepare them for distribution more quickly than General Dynamics. However, this necessitates the eventual incorporation of the op sup material into TO change pages. This is ultimately performed by General Dynamics and obviously entails costly duplication of effort. One possible reason for the length of time taken by General Dynamics is the contention for internal resources needed for F-16 A/B, C/D, and foreign military sale work.

Furthermore, the TO page originals reside at General Dynamics on at least two separate semi-automated document production systems. No provision appears to have been made for transferring these documents directly onto ATOS or any other automated system at OO-ALC/MMEDT, so paper copy must be used as an intermediate representation. Direct transfer of data via communications networks or on magnetic media would be highly preferred. However, a major consideration that would impede transfer of work from General Dynamics to OO-ALC is manpower limitations.

This division of labor also leads to difficulties in the TO modification process as it now stands. For example, modifications may be in preparation at OO-ALC for a TO that is also being changed at General Dynamics. Another example is that an op sup may be issued by OO-ALC, and General

Dynamics may subsequently issue change pages for a completely unrelated change to pages affected by the op sup. This could render the page, paragraph, and line references in the op sup invalid.

4.2.2. Foreign Military Sale (FMS) Issues

At the present time, only the F-16 A/B separate TOs have been transferred to OO-ALC. However, it is the understanding of PDSS project members that this process is likely to begin soon for the F-16 A/B Country Specific Technical Orders (CSTOs). This will necessitate maintaining multiple versions of essentially the same TO (for each CSTO set). Any changes to the U. S. Air Force TO must be examined to determine which CSTOs, if any, should also be changed. These modifications then must be effected and distributed. The respective roles of OO-ALC and General Dynamics must be determined; for instance, will OO-ALC issue op sups or will all changes due to software modifications be issued by General Dynamics as TO change pages? It is clear that transferring the CSTOs will result in additional complexity in OO-ALC TO maintenance activities.

4.3. Activity-Specific Issues

4.3.1. Analysis of Activity 1.0 (Identify and Draft Modifications to Affected TOs)

At present, the process of identifying where modifications need to be made is entirely manual. It involves thumbing through thousands of pages of printed TOs and looking for text or graphics that need to be changed. This activity could benefit greatly from automated assistance. It would be very helpful if assistance could be provided for locating all occurrences of the same text (e.g., a part number) or the same drawing, both within a given TO and across the set of potentially affected TOs. Efficiency and accuracy would be enhanced even further if global changes could be made to these document fragments (e.g., globally replacing the old "PWR ON frame" diagram with the new one). Furthermore, it would be advantageous if text contained within graphics and captions could be searched, since many of the diagrams illustrate the alphanumeric contents of display screens on the F-16.

Since several software engineers need to make changes to the same TOs, it would be beneficial to carefully handle parallel activity to the same document. At present, they simply red-line different paper copies of each TO, which are eventually merged manually. Thus, there is potential for contradictory changes as well as mistakes in the merging process. Automated systems with version control capabilities have developed schemes to successfully control parallel activity, one of which could usefully be employed here.

In order to complete the TO modification process in a timely fashion, it is critical that the red-line changes be accomplished well before flight testing is completed. At present, this may not be the case. Although a few changes may be uncertain until final testing, it is the opinion of PDSS project members that the majority of changes are certain well before that time. Completing this activity allows the subsequent activities to proceed on schedule. If necessary, the few certain changes can be identified for special treatment.

In order to avoid rework, it is important to ensure that changes are being drafted to the most current version of each TO. It is the understanding of project members that there are multiple TO libraries

and that these libraries are not always up to date. If this is found to be true, it should be corrected. However, this improvement will not correct the situation where other changes are being made to a TO at the same time. Thus, communication channels must be established between personnel red-lining the TOs and a point of contact at OO-ALC/MMEDT who will check the status of other changes to each TO, both locally and at General Dynamics. It would then be possible to avoid situations such as the one that occurred recently with TO 1F-16A-34 (Nonnuclear Munitions Delivery Manual). In this unfortunate situation, a completely new revision of the TO reached MMEC a few days after an engineer had finished red-lining the old version.

4.3.2. Analysis of Activity 2.0 (Review and Approve TO Modifications)

Comments regarding this activity focus on its termination and the transfer of information to activity 3.0. A major bottleneck in the process occurs because approved TO changes must be held until they can be completely finalized as a package upon successful flight testing. Probably the single greatest nontechnological improvement could be made by relaxing this termination condition and package transfer concept. One aspect of this improvement would be to allow the approved 252 forms to be handed over to MMEDT on a piecemeal basis rather than as a single package.

The other aspect of the improvement entails an appreciation for the rationale behind the current procedures. PDSS project members have been told that the major concern is to avoid reworking a change once it has been composed and typeset. There is also concern that all affected TOs are held and distributed at once as part of the concurrent release package. Project members feel that this latter concern can be handled by appropriate procedures, while the former can be handled through management of differences in uncertainty. Modifications to many TOs appear to be confined to a small set of very certain changes, e.g., a change in an OFP identification number or a part number. Since these changes are virtually certain to be made, they can be identified early in the red-lining process, and printed copies of the modifications can be completed and in the warehouse before the software is ready to be released. Another set of early changes that were identified are those to graphics depicting display contents. These are primarily user interface changes and, again, are relatively certain, even before flight testing. In addition, since these graphics changes are generally time consuming to format for reproduction, they are good candidates for early release to MMEDT. Of course, some modifications are uncertain until flight testing is completed, and these could be held until that time. With the earlier processing of substantial portions of the modifications, the final changes could be finished in relatively short order.

Applying automation to some or all of these changes, especially the less certain ones, could further reduce the delay in distributing TO modifications. This will be discussed in detail in the following sections.

4.3.3. Analysis of Activity 3.0 (Prepare TO Modifications for Printing)

As just described, streamlining could be achieved by transferring approved changes into this activity earlier. Automating the document production process would also help reduce the delays currently being experienced. Recommendations for these changes will be presented in Section 5. A related item concerns modifications to any TOs that are physically maintained at OO-ALC. If ATOS is to be used for these changes, it would be far more efficient to scan and correct the originals of the affected pages prior to receiving the actual approved changes on the 252 form. ATOS personnel could be

given the list of affected pages and be ready to make the change once the 252 form is received. This is especially meaningful since getting the page into ATOS takes at least as much time as effecting the change to it once it is in the database.

Another possible change would entail having General Dynamics develop change pages in the first place, eliminating the need for OO-ALC to develop and distribute op sups. In fact, MMEDT indicated that they would follow this route if sufficient time was available to have General Dynamics perform the work; however, this is not expected to be the case for most software-related changes. In order for this approach to apply more broadly, it would be necessary to make contractual arrangements with General Dynamics allowing for a shorter time cycle for their work. Presumably, General Dynamics would increase the cost for these changes. Further analysis is needed to ascertain if this would be more cost effective than the current duplication of effort between OO-ALC and General Dynamics.

4.3.4. Analysis of Activity 4.0 (Print Documents)

Difficulties or opportunities for significant improvement by modifications to this activity have not been identified.

4.3.5. Analysis of Activity 5.0 (Distribution)

Difficulties or opportunities for significant improvement by modifications to this activity have not been identified.

4.3.6. Analysis of Activity 6.0 (Prepare TO Change Order to Contractor)

This activity could be enhanced by ensuring that the op sup material is incorporated into the next set of change pages (or next revision) made to the corresponding TO, regardless of whether those changes are processed through OO-ALC. This would obviate the possible difficulty described at the end of Section 4.2.1.

4.3.7. Analysis of Activity 7.0 (Prepare, Print, and Distribute TO Change Pages)

This activity could be enhanced by the type of direct data transfer discussed in Section 4.2.1. General Dynamics' efforts would be positively affected if they could accept the op sup changes in direct automated form for incorporation into change pages. This could result in cost savings to the government. Similarly, it would be highly effective if changes generated by General Dynamics could be transferred directly into a documentation automation system at OO-ALC for use as a new baseline in making future changes. PDSS project members will continue to investigate the possibility of facilitating such transfers.

5. Recommendations for Changes to Methods and Procedures

5.1. Overview

This section outlines recommendations for changes to methods and procedures currently employed in the TO modification process. These recommendations could be implemented without adding any new technology; and it is anticipated that these changes alone will have a substantial positive impact on streamlining the process and improving its timeliness. Furthermore, many of these changes would still be quite useful in conjunction with technological enhancements. As the project progresses, these recommendations will be further refined through cooperation with the key personnel involved in the process steps affected. In addition, more formal estimates of their impact will be developed.

5.2. Recommendations Affecting Activity 1.0

The first recommendation is designed to prevent the possibility of working on an old version of a TO. The simplest way to avoid that is to have MMAR present MMEC with the following information:

- What is the latest version of this document? Make sure this version is the red-lined one.
- Are any other change activities currently in process or pending for this TO within the next, say, three months? This must include questioning General Dynamics personnel, as well as covering OO-ALC processed changes; it would be useful to obtain expected distribution dates on change activities identified.

It might prove useful to routinely collect this sort of information for all F-16 TOs; a report might be prepared biweekly or monthly. However, the less formal approach suggested first should suffice for the needs of this process.

Project members also propose that a record of past changes be used in identifying modifications for future block changes. Many TOs are affected by changes to part numbers and software identification numbers. Indexes should be prepared listing each occurrence of each of these recurring items. These lists could then be consulted when the modifications are being drafted for the next block change. This would prevent the time-consuming process of manually searching for each occurrence of an item like the "PWR ON" diagram, and also lead to high accuracy by ensuring that all occurrences are modified. This procedure entails only a small amount of extra effort on the current block change, with a high payoff in future efficiency and accuracy. Of course, this is not suggested for every type of change, but only for items that are expected to repeat for each block change and are spread over several TOs.

Finally, PDSS project members propose that MMAR management instruct that TO modifications be drafted fairly early in the software change process to allow time to complete the other steps leading to distribution. A precise point remains to be clearly identified, but it is certain that it is far too late to wait until flight testing is completed. In addition, project members suggest categorizing changes by uncertainty level as discussed in the analysis in Section 4.3.2.

5.3. Recommendations Affecting Activities 2.0 and 3.0

A number of changes to the current procedures for transferring information from activity 2.0 to 3.0 have been mentioned in Section 4.3.2. These recommendations entail allowing piecemeal transfers, and categorizing by uncertainty levels. Project members favor the early transmittal of relatively certain changes such as those to part numbers, software identification numbers, and display screens. If possible, confining these early transmittals to the following categories is preferred:

- TOs for which all draft changes are relatively certain
- Graphic changes that are relatively certain.

This would allow considerable amounts of the work of activity 3.0 to begin earlier than it does now, with an attendant improvement in ultimate time performance. If any changes are to be made using ATOS, the affected pages could be entered into the system prior to finalizing the exact change, again increasing parallelism and speeding throughput. Methods remain to be developed for ensuring that all changes are made to each TO and that printed copies are held for concurrent distribution; however, this is not seen as a significant impediment.

5.4. Recommendations Affecting Activity 6.0

Project members suggests that whenever change pages are to be produced to a TO for which an op sup has been issued, General Dynamics should be directed to incorporate the op sup into the formal change pages. This should occur regardless of whether the new change is processed through OO-ALC. This capability might be implemented through the use of a TO change status report of the type suggested in Section 5.2. This report could be scanned and compared tc the list of previously issued op sups. Indeed, such a process could be easily automated.

6. Recommendations for Technology Application

6.1. Overview of TO Production Process

The production of TO modifications, as defined in Section 3, consists of several steps, few of which are automated. In those cases where technology is employed for automation, such as the use of the ATOS, that technology is not current, which limits TO production capabilities at OO-ALC. PDSS project members have selected the following process steps as the most likely candidates for technology insertion:

- Activity 1.0 - Identify and Draft Modifications to Affected TOs
- Activity 2.0 - Review and Approve TO Modifications
- Activity 3.0 - Prepare TO Modifications for Printing.

6.2. Characteristics of the Selected Process Steps

The application of new technology to an existing system does not assure improvement. To determine the feasibility of technology application, the attributes and characteristics of the system must be analyzed.

Project members have analyzed the TO modification process to determine the activities performed, the information flow, the manual and automated methodologies used, and the regulations that apply. Certain aspects and characteristics of the process that impact technology application have emerged:

- A common data store, the TO library, is referenced at each process step.
- There is a moderate level of interaction between process steps.
- The flow of data between steps is not unidirectional.
- There is potential for the reiteration of the process steps. The review process may require the repetition of one or more steps before approval.
- Redundant work is performed. Data captured and modified at one process step may have similar modifications made at another process step.
- Updates to the TO library must be coordinated. More than one user may be updating the same TO concurrently during activity 1.0. There are several copies of the TO library, and each must be maintained.
- It is necessary to maintain cross references to entities within the TO library. Cross references exist between TOs and within a TO.
- Some elements of the TO library are common to many TOs.
- Baselines are established for updating TOs, but configuration management and version control are required to maintain compatibility with the system described by a TO.
- Extensive and complex searches of the TO library are performed during activity 1.0 and activity 2.0 process steps. Both text and graphic elements are searched for.
- The nature of the use of TOs requires accuracy in their information content and consistency in the presentation of that information.
- A formalized review and approval process ensures that responsibility for content is assumed. The AFLC Form 252 provides the authorization to modify the TO content. Changes to the TO library should not be released until authorized.

- The content of TOs is highly structured and consists of text and graphic elements.
- The TO production process steps need to be completed quickly and efficiently. TO modification and the production and distribution of changes comprise the final phase of system maintenance. Delays in distributing TO changes can affect weapons system reliability and maintainability.
- Any technology utilized must consider the OO-ALC offices involved. Both technical and nontechnical users, from a variety of disciplines, require access to the TO library during process activities 1.0, 2.0, and 3.0. Therefore, any technology applied to the TO modification process must be easy to learn and use.

Given the above, the need for information database management is clear: to control concurrent access, to eliminate redundancy, to provide quick search and edit capabilities, to edit merged text and graphics, and to output formatted and paginated text and graphics to an output device. Most of these requirements are well known features of automated information systems. Recent advances in the presentation of text and graphics on high-resolution raster scan displays and laser printers provide the remaining capabilities necessary to achieve an efficient, user-friendly environment for managing TO modifications.

6.3. Production of F-16 A/B TO Modifications

The detailed process activity descriptions in Appendix C define four TO document formats that are produced as the result of a change: 1) op sups; 2) page supplements; 3) change pages; 4) TO revision. The following describes a technology that satisfys the production needs of these document format and discusses how that technology can be used in each of the individual steps in the process model.

6.3.1. Computer-Aided Publishing Systems Workstation Technology

A specific recommendation for inserting technology into the TO production process for the F-16 A/B is to install automated document workstations, also known as computer-aided publishing (CAP) systems, in the MMEC, MMAR, and MMEDT offices and to install one or more of the frequently changed TOs, such as the operational TOs, thereby creating a TO library on the CAP system. The CAP system would be used to identify and draft modifications (red-lining), review and approve, and prepare TO modifications for printing. CAP systems provide comprehensive document management and publishing features. In general, these features meet the needs of the TO modification process defined here and described in Sections 3, 4, and Appendix C.

A typical CAP system consists of: a computer-based intelligent workstation such as an Apollo, Sun, or VAX workstation; a large (19-inch) high-resolution monitor with keyboard; a graphics tablet; a mouse; a variety of input and output devices such as text and graphics scanners, laser printers, and phototypesetting devices; and software to support these devices, along with file/database management, text and graphics editing, composition and formatting, pagination, document assembly, cross referencing, and indexing.

It should be emphasized that these systems provide a "What You See Is What You Get," or WYSIWYG, interactive display. This allows the user to view any page of the document as it will appear on the output device, not just prior to output but at all times during the editing and formatting process. Text and graphics may be created and edited on the same system, as separate entities, and then assembled into pages of the document.

A more detailed description of the CAP system capabilities can be found in the CAP system requirements list in Appendix B.

6.3.2. Start-Up Requirements for TO Production

To make use of the CAP systems for TO modifications, it will be necessary to acquire the most frequently changed TOs in digital format from General Dynamics and to install them on the CAP system. OO-ALC must arrange to get this data on magnetic media from General Dynamics.

It is understood that the format of this data may be incompatible with the specific CAP system; however, most CAP systems provide translation and filter programs for the import and export of text and graphics data. PDSS project members will provide assistance in this area.

Once the TO is converted and installed on the CAP system, the content of the TO will be analyzed to identify common elements. These elements would then be extracted and stored as components of a common element library. This will simplify the maintenance of the TO. The SEI can provide assistance with this analysis. Working with OO-ALC personnel, PDSS project members will help to identify common elements and create strategies for archiving these elements.

As some of the F-16 A/B TO production resides on the ATOS system at OO-ALC, it would be desirable to have an interface to the ATOS system that would allow access to files and to devices, such as the text and graphics scanners, laser proof printer, and VideoComp typesetter, but security issues may prevent this. Alternatives are to provide: access to files through media exchange so that security may be enforced; or access to input/output devices using separate cabling; or separate input/output devices for the CAP system such as graphics/text scanners and laser output devices.

The advantage of this last alternative is in the use of high-resolution laser imaging devices for output. A recent study[2] has shown that good quality technical documentation can be produced on plain paper using laser printers with 600 dpi to 1000 dpi resolution. This would generate cost savings by eliminating film developing, cutting and formatting into pages, page makeup activities, and the associated costs of supplies. The output from a high-resolution laser printer is "camera-ready"; it could be sent directly to printing contractors without further processing or used as a positive for reproduction on duplicating equipment.

The following sections describe recommendations for implementing the CAP system at OO-ALC. Each section describes the current activity and how that activity would be performed on the CAP system. The process descriptions in Appendix C and the process model diagram in Figure 1 are used as the basis for the production steps. It may be helpful to refer to these while reading the recommendations.

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[2]Spencer, David R., *Output Technologies and High Resolution*, The Seybold Report on Publishing Systems (February 16, 1987), pp. 3-20.

6.3.3. Activity 1.0 - Identify and Draft Modifications to Affected TOs

The creation of TO modifications begins with process model activity 1.0, Identify and Draft Modifications to Affected TOs. This task, performed by MMEC or MMARC, consists of manually searching all TOs expected to be affected by the change, locating items to be changed, making a copy of the page, and annotating the copy of the page to indicate changes (red-lining). This is a time-consuming procedure that has a high potential for error and inaccuracy.

To simplify the exposition of the following procedures, PDSS project members have assumed that MMEC performs the actual work of identifying and drafting modifications. While MMARC or others may also perform this process step, MMEC would typically identify and draft the type of modification under discussion. Of course, MMAR actually is responsible for the changes to the TOs.

Using the CAP system the task would be performed as follows:

- MMEC would isolate common elements to be changed during the design process. These would include items such as operational displays, figures, tables, illustrations, warnings, repetitive text descriptions, etc. These elements will have been stored in a common element library on the CAP system.
- To effect a change to a library component, MMEC personnel would locate the element in the CAP system library using an index and/or a document search facility. Search criteria can include text, graphics, and the text contained within graphic elements. The element would then be annotated to indicate the change, or where feasible, the actual change would be made by MMEC personnel. The modified library element would then be filed in the library. Any future references to the element would indicate that a change was in progress.
- After the change is made, a proof copy of the modified item would be printed on the proofing device. Since these are library elements, the change need be made only once for each element; all occurrences of the element in all documents will be changed. Therefore, it is not necessary to search for any additional occurrences of the element or submit a proof copy of each affected page. However, all modified pages could be searched for and printed, if this is required. MMEC may need to do so in order to verify that the element changed has no unexpected effects on other parts of the TO.
- Frequently, the changes required of common elements are known early in the design process and have a low degree of uncertainty. Therefore, these changes could be made before testing is completed.
- To complete the remaining modifications, which consist of changes to items not contained in the common element library, MMEC personnel would use the CAP system document search facility to locate references and keywords relevant to the function or system to be changed. An item requiring change would be annotated; or where feasible, the actual change would be made by MMEC personnel. The TO would then be filed back to the CAP system TO library. Any future references to this TO would indicate that a change was in progress.
- After completing the change, a proof copy of the modified page would be printed on the proofing device. As an alternative to printing proof copies, or in addition to, all changed pages and library elements could be assembled into a separate document for manual or electronic review.

The CAP system's automated search and replace capabilities, document annotating and editing, and common element libraries make the red-lining activity more efficient and less prone to error. As all

MMEC personnel access the same database, changes to the same page from different sources will be made in concert, thus eliminating the need for a coordinating effort after software changes and red-lining are complete.

6.3.4. Activity 2.0 - Review and Approve TO Modifications

Upon completing the identification and drafting activity, the modifications are submitted to MMAR for review and approval. This completely manual process, described in process model activity 2.0, involves verification of the changes submitted. It includes a manual review of the affected TOs to ensure that no changes have been omitted, no unnecessary changes were included, and no other changes in progress interact with this change in an undesirable manner.

Using the CAP system, this task would be performed as follows:

- TO modifications, prepared on the CAP system by MMEC, could be verified in several ways:
  - Proof copies of the annotated or modified items, printed by MMEC, could be used to verify that the changes requested are correct.
  - If a "change document" was assembled as described previously, this document could be reviewed to verify that the changes requested are correct.
  - MMARC could also use the document search facility to locate annotated or modified items within the TO and then to verify that the changes requested are correct.
- To verify that all the necessary changes have been made, MMARC would use the document search capabilities to locate potential change. Each item found in this manner should have been changed or annotated by MMEC.
- To verify that no unnecessary changes have been made, MMARC would use the document search capabilities to locate all annotated or modified items. Each item found in this manner would then be verified to determine if it is a valid change.
- Since MMEC personnel work with the same copy of the TO at all times, no additional effort is required to verify that other modifications in progress interact unfavorably with modifications under review. The CAP system file/database management, configuration management, and version control features eliminate the problems that can occur when concurrent updates are performed in an uncontrolled environment.
- Any annotations or modifications that are in error would be edited by MMAR personnel where feasible; otherwise, an annotation would be appended to the MMEC annotation/change and a proof copy printed and returned to MMEC for review. Modifications that are correct would be annotated by MMARC to indicate approval. This mechanism would serve as an electronic verification of review and approval by MMAR personnel before processing by MMEDT.
- When the modifications are complete, proof copies would be printed and attached to an AFLC Form 252, then submitted to MMEDT for processing. Alternately, if a change document was assembled, it could be printed for attachment to the form. Use of the form would be strictly a formality, as MMEDT personnel would use the CAP system to process the change requests, eliminating the need for a detailed change request to accompany the 252 form.

As previously stated for activity 1.0, the CAP system provides greater efficiency and reliability than the current manual systems. Process steps can be completed in less time and the potential for iteration of steps is decreased.

6.3.5. Activity 3.0 - Prepare TO Modifications for Printing

Upon completing activity 2.0, MMAR submits the change requests to MMEDT using AFLC Form 252. MMEDT prepares the TO modifications for printing as described in process activity 3.0.

MMEDT is responsible for editing the changes to meet content and formatting requirements, creating any additional text or graphics when required, typesetting and composing the changes, and submitting the changes to DARA for printing.

MMEDT may use prime contractors, overflow contractors, and the ATOS system to fulfill these responsibilities. However, for the F-16 A/B TOs under discussion, the prime contractor, General Dynamics, produces most TO modifications, except op sups.

MMEDT does use the ATOS system to create, edit, typeset, and compose the TO modifications for some F-16 A/B commodities TOs.

ATOS was created to automate the production of TO changes. ATOS consists of several off-the-shelf subsystems, from different vendors, that have been integrated to provide a limited TO production capability.

To create TO changes using ATOS, text and graphics must be scanned or created, edited, and previewed. Finally, text and graphics must be merged into pages, previewed, and the output must go to a phototypesetter. ATOS uses a different system for each of these steps.

Graphics are created on an Autotrol workstation or scanned on a III raster scanner, then converted to vector format and edited by an Anatech vectorizer; and finally, they are sent to the Autotrol workstation for additional editing. When completed, the graphics are sent to a VAX 11/785 for storage in an ATOS graphics database.

Text is created on Datalogics editing terminals or scanned by a Kurzweil optical character reader (OCR), then edited on the Datalogics terminals. During text editing, generic markup codes are inserted to control document formatting. Text is then composed and previewed on a softcopy preview terminal.

The text and graphics are then merged and previewed on a page makeup subsystem. When a page contains errors, a proof is made on a laser printer, the error is red-lined, and the proof is returned to the graphics or text entry personnel for correction. The appropriate steps are then repeated until the page is correct. While it is possible to correct errors at the page makeup subsystem, there is no mechanism to store these changes back into the 11/785 database; therefore, all pagination problems require reiteration of the graphics and/or text editing steps.

After a TO change is completed, it is archived to a tape library.

While the ATOS system provides a semi-automated approach to the typesetting and composition of TO changes, it does not provide the document production facilities of a typical CAP system. This is due to improper subsystem integration, a lack of data management capabilities, and inadequate data storage capacity.

It is understood that only op sups for the F-16 A/B TOs are normally produced at OO-ALC (excluding the commodities TOs). However, a description is given of how the CAP system might be used to produce four of the document types used to publish TOs.

Using the CAP system to prepare the TO for publication, the following steps are performed:

- Upon receipt of AFLC Form 252 and the attached TO modification requests, MMEDT personnel use the document search features of the CAP system to find the annotated or changed areas of the TO specified on the 252 form. Alternately, if a change document has been assembled, then it is used as a source for the changes.
- MMEDT edits the annotated or changed areas for content and format. The interactive WYSIWYG features of the CAP system allow MMEDT to view the changes to the document as they are made.
- When completed, the changed areas of the document are printed on the proofing device for review by MMEDT.
- After all changes have been reviewed, document assembly begins.

Each TO modification is published in one of four document types: 1) op sups; 2) page supplements; 3) change pages; and 4) TO revisions.

Op sup pages consist of references to the page, paragraph, line, etc. to be changed followed by the addition, deletion, or modification to be made.

Using the CAP system, op sups would be produced as follows:

- MMEDT would locate and extract the modified areas of the TO using the document search and editing features.
- The extracted text would be merged into an op sup document along with the page reference for the modification.
- When all modifications have been extracted and merged into an op sup document, a proof copy would be printed for review.
- A final version of the op sup document would then be printed on the output device, either the VideoComp 570 or a high-resolution laser printer, and submitted to DARA for printing.
- Although preparation of op sups could be created from "scratch," without extracting the modifications from the TO, this procedure ensures that the TO library is synchronized with the op sups.

Change pages are new or modified pages that are inserted into the TO in place of the page they affect.

Page supplements, or "green pages" as they are called, are similar to change pages. They are modified pages to be inserted in the TO, but they contain only the modified portion of the page. When inserted into the TO, they are inserted opposite the page they affect.

Using the CAP system, page supplements and change pages would be produced as follows:

- After completing the TO modifications, MMEDT would use the document search feature to locate, extract, and merge all changed pages into a "changed pages" document.

- The document would then be proofed and processed for printing in the same manner as described for op sups.

Although no TO revisions for operational TOs have ever been produced by OO-ALC, this is by far the easiest type of modification to produce. After completing the TO modifications, MMEDT personnel simply output the entire document.

Use of the CAP system by MMEDT to produce TO modifications will be the best demonstration of the effect of technology application. Document production is not only easier, but the repetitive work performed by MMEDT is eliminated by distributing the work function and capturing needed information at the source.

6.4. Application of CAP Technology to Other Systems

6.4.1. Time Compliance TOs (TCTO)

The scope of the PDSS project's modeling and analysis has not yet included TCTOs; however, the use of the CAP system to produce TCTO's should be explored.

6.4.2. Application to Other Systems Involved in PMRT

The production of F-16 A/B TOs at OO-ALC is complicated by the state of PMRT for the F-16 A/B. Currently, several thousand outstanding TO items are still being managed by the F-16 SPO. OO-ALC does have TO responsibility for other systems that have been fully transferred. The application of CAP technology to these systems would provide the same benefits as described for the F-16 A/B, possibly without the problems associated with the F-16 A/B program.

6.4.3. Application to Systems in Initial Acquisition Phase

The inability to exchange information in electronic form between the ALC and the prime contractor for a weapons system, at or before PMRT, limits the ability of the ALC to internally manage and produce TOs. For systems that are in the acquisition phase, specifications should include an information intelligence exchange capability. The technology and standards required to accomplish this are available today. Requiring a contractor to conform to these standards for the weapons system data created during development would simplify the transfer of program management to the ALC. Thus, the significant costs pertaining to weapons system maintenance would be reduced.

7. Summary

The information presented in this report details how the TO production process can be modified for productivity gains and how technology can be applied to that process. The activities of the PDSS project should be viewed as a study, not a solution. It is most likely that all of these recommendations are not able to be implemented; however, the project should be able to predict the impact of implementing all of the changes and associated technologies. Future reports will present that information.

Appendix A: List of Acronyms and Office Symbols

AFB	Air Force Base
AFLC	Air Force Logistics Command
ALC	Air Logistics Center
AMC	Army Materiel Command
ATOS	Automated Technical Order System
CAPS	Computer-Aided Publishing System
CSTO	Country Specific Technical Order
DARA	Directorate of Administration, Reprographics Division, (office symbol)
DOD	Department of Defense
dpi	dots per inch
FCDSSA	Fleet Combat Decision System Support Agency
FMS	Foreign Military Sale
GPO	Government Printing Office
HUD	Heads Up Display
MMAR	Directorate of Materiel Management, Engineering and Reliability Branch (office symbol)
MMEC	Directorate of Materiel Management, Engineering Division, Aircraft Computer Resources Branch (office symbol)
MMEDT	Directorate of Materiel Management, Engineering Division,Operations and Support Branch, TO Section (office symbol)
OC-ALC	Oklahoma City Air Logistics Center
OCR	Optical Character Reader
OFP	Operational Flight Program
OO-ALC	Ogden Air Logistics Center
PDSS	Post Deployment Software Support
PMTC	Pacific Missile Test Center
PMRT	Program Management Responsibility Transfer
SCP	Software Change Process
SEI	Software Engineering Institute
SPM	Systems Program Manager
SPO	Systems Program Office
TAC	Tactical Air Command
TCTO	Time Compliance Technical Order
TO	Technical Order
TODCO	Technical Order Distribution Control Office
TODO	Technical Order Distribution Office
TOPS	Technical Order Page Supplement
UPF	Universal Page Format
WYSIWYG	What You See Is What You Get

Appendix B: Computer-Aided Publishing System Requirements List

1. User interface
    a. Icon or menu based (pull down or pop up) for fast learning curve.
    b. Mouse and graphics tablet to simplify user input.
    c. Full function, word processing style keyboard with function keys and cursor pad for text input during editing and annotating processes.
    d. Large, high-resolution, flicker-free display.
    e. WYSIWYG document display, with full-page display capabilities, accurate text and graphics representation with respect to justification, line endings, positioning, representation of type height and width, etc. The differences between a document representation on the display and on an output device, resulting from generic font representation or differences in device resolution, must not be so severe as to cause recomposition of a page due to poor justification, positioning problems with respect to graphics and text, or other similar errors.
    f. Full interactive editing of integrated text and graphics in WYSIWYG mode.
2. Input device support
    a. Raster graphics scanning device interface for the input of line art.
    b. OCR interface for the input of character data, including the Kurzweil OCR.
    c. PC or word processor interface.
    d. Magnetic tape containing graphics in Autotrol format or IGES format, and text in a generic code format such as SGML.
    e. Local area network (LAN) interface using one of the above formats.
    f. Conversion programs that filter imported text files for use on the system.
3. Output device support
    a. Laser printers, using a page description language such as PostScript, Interpress, imPRESS, RIPrint, or a phototypesetter language. Specific devices supported should include any PostScript-compatible laser printer, the Tegra Genesis, data recording systems Laser-Scribe, or Printware's 720 IQ.
    b. Phototypesetters, using Autologics, Compugraphic, Linotron, or III VideoComp 570 UPF format.
    c. Magnetic tape containing graphics in Autotrol or IGES format, and text in generic code format such as SGML.
    d. LAN using one of the above formats.
4. Creation and editing of text, tables, and graphics
    a. The ability to enter text at the workstation keyboard and to merge into the current document text created at any of the input sources described above or stored in libraries, files, or other documents.
    b. The ability to edit text contained in libraries, files, or documents using a conventional text editor, and to do so interactively, in WYSIWYG mode, during document preparation.

c. A search-and-replace function for locating and changing text within documents and libraries, including the text within tables and graphics elements.

d. The ability to create complex editing and command sequences with user-defined macros that can be filed and executed, using function keys or user-tailored menus or icons.

e. The ability to annotate the document with comments that will appear on the display, can be searched for as an entity, and can be content searched as part of the document. The annotations will appear on the display, but will not appear in the document when it is output.

f. A spelling checker that acts on text within the document, including text in graphics elements, with user-expandable dictionary for application-specific requirements.

g. The ability to create and edit tables including text and graphics within tables, specification of rule weights and styles, alignment of data within cells, insertion and deletion of columns and rows, and specification of composition parameters.

h. The ability to extract, move, and duplicate text and graphics while editing in WYSIWYG mode.

i. The ability to create graphics using: standard basic elements such as rectangles, circles, ellipses, vectors, horizontal and vertical lines, arcs, polylines; adjustable line weights and styles; arrowheads and other "clip art" symbols; user-created libraries; free-hand drawings; and isometric drawing capability.

j. The ability to edit vector and raster graphics created on CAD/CAM systems and graphics scanners, including inserting, rotating, cropping, sizing, duplicating, stretching, flopping, pixel editing, painting, blending, fading, filling, and aligning. Text components of graphics, such as callouts and labels, must be addressable as part of the graphics and as separate text entities, to allow for editing, formatting, etc. as if they were normal text.

5. Document design, composition, and pagination

a. Interactive document design facility for creating a structured set of specifications for the components of a document, including the definition of attributes for each element in the document so that composition, pagination, and document assembly attributes are not included in the document text.

b. The document specification, and the pagination facility, must accommodate MIL-STDs and waivers as they apply to the F-16 A/B. The areas of concern are page format, typestyles, typesizes, and sectioning as these relate to document components such as front matter, title page, effective page list, table of contents, main body of text, chapters, four levels of section heads and paragraphs, itemized and enumerated lists, references, tables, illustrations, footnotes, warnings, page headings, page footings, and rear matter.

c. User control of justification parameters such as character and word spacing, kerning, ragged left/right and justified body copy, flush left/right and centered headings.

d. Automatic hyphenation with user-expandable dictionary and adjustable hyphenation parameters, such as consecutive hyphenated lines, number of characters before and after hyphen, hyphenation fence, and word initiator/terminator characters.

e. User control of pagination and document assembly parameters, by page type

within the document, such as: widow and orphan treatment; vertical justification; columns per page; column balancing; page fidelity; position anchors; page rules; page header/footer position; footnote position; left-hand/right-hand page treatment; chapter, page, section, subsection, list, table, figure, and footnote numbering sequence.

f. User control of pagination region within the document, for repagination during editing.

6. Cross referencing and indexing

a. The ability to create cross references to sections, figures, graphics, and user-defined tags.

b. The ability to create a table of contents.

c. The ability to create a multilevel index with user-specified tags and sort parameters.

d. The ability to create an index of changed pages.

7. File/database management, configuration management, and version control

a. The ability to support multiuser access to a single document, including a protection mechanism to control concurrent updates.

b. The ability to maintain large documents, including division of large documents into sections and the ability to merge the sections back into a single document. Also, the ability to access these sections by request in order to retrieve a specific section for display. For example, a hierarchical structure such as book, chapter, section, page, etc., with a file positioning mechanism that allows the user to select a specific starting point in the document when editing, paginating, etc.

c. The ability to maintain libraries of graphics and/or text elements that can be merged into documents on demand at document assembly.

d. A provision for file security that allows access controls to be established by user and class of user.

e. An archiving mechanism for backup/restore purposes.

f. A configuration management and version control capability that supports multiple versions of the same document, with a document version status to indicate the state of a version. Library references within the document must also be resolved relative to the current revision levels of the document and the library element referenced.

8. Communications

a. Communications facilities must provide for the interconnection of several workstations, file servers, and input/output devices on a LAN.

b. The network must support the exchange of documents, libraries, and other files between nodes, at the request of a workstation node. All input and output devices must be addressable from workstation nodes.

c. Support for the input and output devices described elsewhere must be provided.

9. System and Job Control

a. System configuration, generation, maintenance, and control.

b. Network configuration, maintenance, and control.

c. Application configuration, maintenance, and control.

d. Management job control statistics and reporting functions.

e. Resource availability status.

10. Hardware

a. Standard off-the-shelf hardware components similar to Apollo, Sun, or VAX workstations.

b. Large (19-inch) high-resolution monitor.

c. Mouse and graphics tablet.

d. Keyboard with standard keys, cursor control, and function keypad.

e. Minimum 80mb disk capacity with expansion through add-on drives or distributed data storage using LAN.

f. Magnetic tape.

Appendix C: Detailed Activity Descriptions

C.a. Activity 1.0 - Identify and Draft Modifications to Affected TOs

ID Number: 1.0

Activity Name: Identify and Draft Modifications to Affected TOs

Activity Description:
The major point of this activity is to indicate where changes must be made to existing TOs to correspond to the current block change of the F-16 A/B OFP avionics software. The bulk of this work is accomplished by MMEC engineers; however, some work is performed by MMARC personnel. The software engineers in MMEC, who perform the software design work for the change block, are in a good position from a technical standpoint to accomplish this activity. MMARC personnel have taken on the responsibility of making changes to TOs for which modification only involves a change in part numbers.

Currently, several different engineers in MMEC, working on different components of the OFP software (the Stores Management System, Radar, Fire Control Computer, HUD, etc.) make the changes for which MMEC is responsible. The work proceeds in parallel and may often involve marking up different copies of the same TO, leading to a future necessity to merge these red-lined documents.

The activity is entirely manual, involving thumbing through the manuals and red-lining. No automated assistance is available to aid in locating text or diagrams that need to be modified.

Office Accomplishing Work: Primarily OO-ALC/MMEC, also OO-ALC/MMARC

Timing:

- Commencement—Theoretically, this activity can begin when the software design is well developed; however, the time frame varies among individual software engineers. Some engineers begin early in the software change process, in parallel with modifications to the avionics manual and B5 specs. Others delay until flight testing is successful.
- Termination—This activity ends when the individual believes that he has made all relevant changes to the TOs.

Inputs:

- List of TOs that are probably affected.
- Definition and design of software changes being made.
- Current version of affected TOs, provided by TO library.
- Avionics manual—a manual, for use by the engineering group, that describes the avionics software. This manual, which resides on the Xerox STAR system, is updated to keep it current with software changes. Although this document may be an input, in many cases it need not be referred to.
- Feedback from activity 2.0 leading to revisions of draft changes.

Outputs:

- Draft modifications to the TOs in the form of red-lined paper copy.

C.b. Activity 2.0 - Review and Approve TO Modifications

ID Number: 2.0

Activity Name: Review and Approve TO Modifications

Activity Description:
This activity entails reviewing and ultimately approving the detailed changes to be made. Changes are reviewed and approved by personnel in MMAR. Formal approval is indicated on an AFLC Form 252, prepared as part of this activity. One aspect of this activity is to achieve some degree of assurance that all modifications that should be made due to the software changes are actually made and that no extraneous modifications are inadvertently included. These statements should be true at the level of each individual TO, as well as across the set of all F-16 A/B TOs.

As with activity 1.0, this is an entirely manual process, with no automated assistance.

Office of responsibility: OO-ALC/MMARC

Timing:

- Commencement—This activity begins when red-lined TOs are delivered from engineering or completed within MMARC. Work can proceed on an incremental basis, so it is not necessary for all TOs to be delivered before work begins.
- Termination—This activity could terminate for each TO as soon as its draft changes have been approved and a corresponding AFLC Form 252 has been completed. However, current organizational rules prohibit the form from being forwarded to MMEDT (corresponding to the output data flow) until the software changes have been validated and verified. Thus, at present, this activity does not end until successful flight testing.

Inputs:

- Draft modifications in the form of red-lined TOs.
- TO library may also be consulted for latest versions of these or related documents.

Outputs:

- Approved changes to TOs, formalized by AFLC Form 252, often with attached red-lined TO.
- Feedback may also be sent to engineering for revision of draft modifications.

C.c. Activity 3.0 - Prepare TO Modifications for Printing

ID Number: 3.0

Activity Name: Prepare TO Modifications for Printing

Activity Description:
The primary purpose of this activity is to compose and typeset the approved modifications, resulting in a reproducible copy that is sent on for printing. Conceptually, a number of document types may be produced for this purpose; these include op sups, interim op sups, TO page supplements (TOPS), change pages, and TO revisions. However, only two of these are routinely used for the F-16 changes under consideration: op sups and change pages. The determination of which document type to use depends primarily on whether the given TO is physically maintained at OO-ALC or whether General Dynamics is contracted to maintain that TO. The bulk of TOs affected by F-16 OFP avionics software changes are actually maintained by General Dynamics. In this case, OO-ALC normally produces and distributes op sups, which General Dynamics ultimately incorporates into change pages or TO revisions. For the TOs that OO-ALC physically maintains (if any), change pages are produced and distributed, probably utilizing the ATOS system, Phase 1.

A variety of steps and personnel are involved in the process of producing the typeset document for reproduction. Text is entered and typeset, and it may undergo minor editing from that indicated on the AFLC Form 252 to conform to the TO's style. Also, graphics are entered by drafting personnel to implement the changes to figures in the TO. Text and graphics are then combined. The actual production work may be performed by OO-ALC personnel or by a local overflow contractor. A quality control check on the reproducible copy is performed by MMEDT by comparing it to the original AFLC Form 252 specifications.

Air Force regulations require that these changes be distributed to the field within 165 days after receipt of the completed AFLC Form 252 (see TO 00-5-1). Allowing 15 days for printing, this gives MMEDT a maximum of 150 days to develop reproducible copy, though it is the understanding of PDSS project members that op sups are generally produced in much less time than this regulatory maximum.

Preparation for printing and distribution also involves querying the GO22 system at OC-ALC. This system provides information on the number of copies needed and produces mailing labels for initial distribution. In addition, the time allowed for printing is determined and communicated to DARA. Fifteen days are allowed for the printing of documents to be incorporated into a concurrent release package, which in this case would include both op sups and change pages. (Normally, 45 days are allowed for printing of change pages.)

Office Accomplishing Work: OO-ALC/MMEDT

Timing:

- Commencement—This activity begins with the receipt of the approved AFLC Form 252. The timing of that event has already been discussed under the activity 2.0 description. At present, all 252 forms arrive as a package for the block change. It is possible that a portion of the work could be broken out and begun sooner in order to relieve some of the time pressure on MMEDT.
- Termination—The activity ends when the reproducible copies are forwarded to DARA and the mailing labels are forwarded to the warehouse.

Inputs:

- Approved changes, formalized on AFLC Form 252.
- TO library in MMED is consulted to assure that changes are being made to the latest version of the TOs.
- Mailing labels for those on the initial distribution list for each affected TO, as well as information on how many copies to have printed, provided by the GO22 system at OC-ALC.
- In some cases, the ATOS database and system may be used to compose and typeset the reproducible copy.

Outputs:

- Reproducible copy of each affected TO is prepared as the major output of this activity.
- Mailing labels, which are acquired from GO22 at OC-ALC and forwarded to the TO warehouse.
- If ATOS is utilized, changes are made to its database.

C.d. Activity 4.0 - Print Documents

ID Number: 4.0

Activity Name: Print Documents

Activity Description:
The purpose of this activity is to print the required number of copies of each op sup or group of TO change pages. Three options are available for the actual printing of each job:

- printing by shop on the base
- printing by local contractor (19 printers currently on direct deal contracts through GPO)
- work through GPO regional office in Denver.

The last option is used only when the job cannot be accomplished by the other means. Choosing which of the first two approaches to use involves considering the workload in the base printing facility and the rules of the Joint Committee on Printing (JCP - a Congressional committee). JCP rules specify situations when printing must be accomplished through GPO, based on numbers of copies produced, total pages to be printed, and the type of printing equipment on base.

The time limit for printing is generally 15 days. This requirement is met in most cases; if there is a delay, it is usually just a couple of days.

Office Accomplishing Work: OO-ALC/DARA

Timing:

- Commencement—This activity begins for each TO as the reproducible copy is received from MMEDT.
- Termination—It ends when the printed documents have been received and sent to the TO warehouse for distribution.

Inputs:

- Reproducible copy of each affected TO.

Outputs:

- Printed copies of each affected TO.

C.e. Activity 5.0 - Distribution

ID Number: 5.0

Activity Name: Distribution

Activity Description:
The purpose of this activity is to provide the appropriate number of printed documents (i.e., op sups and TO change pages) to each user organization on the initial distribution list. This activity is managed by the TODCO, an MMEDT function. Shipment of the various TO modifications must be coordinated with the shipment of the actual computer tapes containing the modified software and the corresponding TCTOs, as this is all concurrent release material. The TO documents are packaged and addressed using the mailing labels acquired from the GO22 system at OC-ALC, then they are metered and mailed.

Office Accomplishing Work: OO-ALC/MMEDT (TODCO)

Timing:

- Commencement—This activity begins when the printed copies of all the TO modifications for the block change have been delivered to the TO warehouse. Actual distribution must be coordinated with the distribution of the tapes containing the software changes and the TCTOs describing installation procedures. These items are required to be released concurrently; that is, they are to be shipped within seven days of each other.
- Termination—This activity ends when the initial distribution copies have been mailed.

Inputs:

- Printed documents, i.e., op sups and change pages.
- Mailing labels for initial distribution, from the GO22 system at OC-ALC.

Outputs:

- Printed documents are mailed to all users on the initial distribution list; copies also go to the TO libraries at Hill AFB, including that at MMED.
- Copies of op sups are filed at MMEDT for later incorporation into TO change pages.

C.f. Activity 6.0 - Prepare TO Change Order to Contractor

ID Number: 6.0

Activity Name: Prepare TO Change Order to Contractor

Activity Description:
The purpose of this activity is to incorporate TO changes published as op sups into actual TO change pages. This activity proceeds independently for each TO for which an op sup was prepared. Since there is no time limit on the validity of an op sup, there is no perceived rush to convert the information into change pages. Generally, no action is taken until the next time a change processed through OO-ALC/MMEDT is required. This change may be (and usually is) entirely independent and unrelated to the previous modifications prompted by the last software block change. If the new change is not urgent, then a change order is prepared directing General Dynamics to produce and distribute change pages incorporating both the new change and the previous op sup changes. If the new change is more urgent, it may also be issued as an op sup, and both supplements would be held until yet another change is required. Thus, the amount of time before the change order is issued is highly variable for each affected TO.

Office Accomplishing Work: OO-ALC/MMEDT

Timing:

- Commencement—The timing of this activity is quite complex, and is described above. It is noteworthy that change orders are prepared monthly for transmittal to General Dynamics, so up to 30 days may be involved here for processing.
- Termination—This activity ends for each TO when the appropriate change order has been transmitted to GD.

Inputs:

- Copy of each op sup issued.

Outputs:

- TO change order directed to contractor (General Dynamics). This generally includes a paper copy of the op sup to be incorporated into change pages.

C.g. Activity 7.0 - Prepare, Print, and Distribute TO Change Pages

ID Number: 7.0

Activity Name: Prepare, Print, and Distribute TO Change Pages

Activity Description:
The primary purpose of this activity is to prepare, print, and distribute formal TO change pages corresponding to the TO Change Order received from OO-ALC/MMEDT. This activity is accomplished by General Dynamics for those TOs which General Dynamics is contracted to maintain and for which OO-ALC has prepared op sups. This activity is similar in content to activities 3.0, 4.0, and 5.0; however, since it is somewhat ancillary to the activities in which the PDSS project is primarily interested, it is described at a less detailed level.

General Dynamics composes and typesets change pages corresponding to the previously issued op sups and 252 forms forwarded to them as part of the change order. Project members do not yet have a clear understanding of the extent to which automated assistance is available for this work. OO-ALC's contract with General Dynamics allows 90 days for preparing the reproducible copy, which is then forwarded to a GPO printer, probably in the Fort Worth area. The printer is given mailing labels for the initial distribution users, and mails out the completed documents. With 45 days allowed for printing, a total of 135 days is allowed for this activity. It is noteworthy that these change pages are NOT part of a concurrent release package. Thus, each affected TO can be handled relatively independently.

Office Accomplishing Work: General Dynamics executes; OO-ALC/MMEDT manages activity

Timing:

- Commencement—For those changes under consideration, this activity begins when General Dynamics receives a TO change order from OO-ALC.
- Termination—This activity ends when the printed documents are distributed to those on the initial distribution list. Contractually, General Dynamics has 90 days after receiving the Change Order to send it to the printer; printing is to be completed within an additional 45 days.

Inputs:

- TO Change Order, from OO-ALC MMEDT.
- Mailing labels, produced by the GO22 system at OC-ALC.

Outputs:

- Printed TO change pages, mailed to all users on the initial distribution list. Copies also go to the TO libraries at Hill, including the one at MMED.

REPORT DOCUMENTATION PAGE

1a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED	1b. RESTRICTIVE MARKINGS NONE
2a. SECURITY CLASSIFICATION AUTHORITY N/A	3. DISTRIBUTION/AVAILABILITY OF REPORT APPROVED FOR PUBLIC RELEASE DISTRIBUTION UNLIMITED
2b. DECLASSIFICATION/DOWNGRADING SCHEDULE N/A	
4. PERFORMING ORGANIZATION REPORT NUMBER(S) CMU/SEI/-87-TR-12	5. MONITORING ORGANIZATION REPORT NUMBER(S) ESD-TR-87-113
6a. NAME OF PERFORMING ORGANIZATION SOFTWARE ENGINEERING INSTITUTE 6b. OFFICE SYMBOL (If applicable) SEI	7a. NAME OF MONITORING ORGANIZATION SEI JOINT PROGRAM OFFICE
6c. ADDRESS (City, State and ZIP Code) CARNEGIE MELLON UNIVERSITY PITTSBURGH, PA 15213	7b. ADDRESS (City, State and ZIP Code) ESD/XRS1 HANSCOM AIR FORCE BASE, MA 01731
8a. NAME OF FUNDING/SPONSORING ORGANIZATION SEI JOINT PROGRAM OFFICE 8b. OFFICE SYMBOL (If applicable) SEI JPO	9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER F1962885C0003
8c. ADDRESS (City, State and ZIP Code) CARNEGIE MELLON UNIVERSITY SOFTWARE ENGINEERING INSTITUTE JPO PITTSBURGH, PA 15213	10. SOURCE OF FUNDING NOS. PROGRAM ELEMENT NO.: PROJECT NO.: N/A TASK NO.: N/A WORK UNIT NO.: N/A
11. TITLE (Include Security Classification) THE ANALYSIS OF THE TECHNICAL ORDER PRODUCT. PROCESS AT OGDEN AIR LOGISTICS CENTER AND RECOMMENDATIONS FOR THE IMPROVEMENT OF THE PROCESS	
12. PERSONAL AUTHOR(S) STAN PRZYBYLINSKI, GREG HANSEN, MARC KELLNER, JIM OVER,	
13a. TYPE OF REPORT FINAL 13b. TIME COVERED FROM _____ TO _____	14. DATE OF REPORT (Yr., Mo., Day) JANUARY, 1988 15. PAGE COUNT 39
16. SUPPLEMENTARY NOTATION	
17. COSATI CODES FIELD / GROUP / SUB. GR.	18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number)

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

THIS REPORT DETAILS THE PROCESS USED BY OGDEN AIR LOGISTICS CENTER TO MAINTAIN OPERATIONAL FLIGHT PROGRAM TECHNICAL ORDERS FOR THE F-16 AIRPLANE. IT IS OF PARTICULAR INTEREST TO OGDEN BECAUSE IT MAKES RECOMMENDATIONS FOR THE IMPROVEMENT OF THE PROCESS AND ALSO RECOMMENDATIONS FOR TECHNOLOGY INSERTION. SINCE THE TECHNICAL ORDER MODIFICATION PROCESS IS NOT ENTIRELY DIFFERENT FROM DOCUMENTATION MAINTENANCE ACTIVITIES IN INDUSTRY, THIS REPORT IS OF GENERAL INTEREST AND WIDELY APPLICABLE TO DOCUMENTATION PROCESSES IN THE SOFTWARE COMMUNITY AT LARGE.

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS ☒	21. ABSTRACT SECURITY CLASSIFICATION UNCLASSIFIED, UNLIMITED
22a. NAME OF RESPONSIBLE INDIVIDUAL KARL SHINGLER	22b. TELEPHONE NUMBER (Include Area Code) (412) 268-7630 22c. OFFICE SYMBOL SEI JPO

DD FORM 1473, 83 APR EDITION OF 1 JAN 73 IS OBSOLETE.